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FERRITE DEVELOPMENT

Report No. 53 | Contract No. 6

Signal Corps Contract | DA-36-039

SC-89222

Dept. of Army Project 3-93-01-701

Second Quarterly Report

1 September 1962 to 30 November 1962

DIVISION OF INDIANA GENERAL CORPORATION

INDIANA GENERAL CORPORATION
ELECTRONICS DIVISION
RESEARCH DEPARTMENT
KEASBEY, NEW JERSEY — Telephone VAlley 6-5100,

FERRITE DEVELOPMENT

Report No. 53	Contract No. 6
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Dept. of Army Project 3093-01-70

SECOND QUARTERLY REPORT

1 September 1962 to 30 November 1962

OBJECT: Conduct investigations and develop magnetic high frequency core materials.

REPORTED BY: Dr. Kurt F. Wetzel, Chemist
Dr. Eberhard Schwabe, Physicist
Sigismund Golian, Ceramic Engineer
Daniel Sullivan, Ceramic Engineer

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PART I TEMPERATURE-STABLE MANGANESE-ZINC FERRITES

The effect of small changes in the iron ratio of materials containing 50% by weight of calcines were studied. The introduction of calcines resulted in considerably improved $\mu_o Q$-products, but did not affect the performance of μ_o vs. temperature. Best over-all magnetic results were obtained with formulas calculated to contain slightly less than 53.0 mol% iron oxide.

PART II INITIAL PERMEABILITY OF MANGANESE-ZINC FERRITES IN THE TEMPERATURE RANGE -196°C to +150°C

Three types of materials were studied containing 50, 53, and 56 mol% iron oxide. With all three types, the permeability at -196°C was decreased drastically. The materials containing iron excess display the so-called "camel-back effect", that is a peak value of μ_o at approximately -80°C, followed by a decline up to approximately 0°C, from which point μ_o increases again with increasing temperature. This phenomenon is most pronounced with the material containing 56 mol% iron and is considered to be due to the formation of $FeO \cdot Fe_2O_3$.

PART III DISACCOMMODATION OF COMMERCIALLY PRODUCED MATERIALS

The aging effect on several production materials, manganese-zinc ferrites and (porous) nickel-zinc ferrites, was studied over a period of several months. It appears that the iron ratio had major bearing on the deviation of μ_o vs. time.

PART IV TEMPERATURE-STABLE MATERIALS IN THE 2-12 MC/S RANGE

Investigated were the effect of different milling and firing techniques upon the magnetic properties of material MF-6835-3. In order to obtain high $\mu_o Q$-products combined with low temperature coefficients of μ_o, grain sizes in the fired materials have to be maintained at less than 3 microns.

ABSTRACTS (continued)

PART V ZERO-FIELD FERRITES IN THE 50-400 MC/S RANGE

Two approaches to improving the material were investigated; annealing at different temperatures and changing the iron oxide ratio. Neither brought about an improvement. Work on this type of material is considered as concluded.

PART I

TEMPERATURE-STABLE MANGANESE-ZINC FERRITES

In Report No. 52 (1 June 1962 to 31 August 1962), pages 8 and 9, Tables 263 and 264, Graphs 549 to 554, results were presented on the magnetic effect of small changes of the iron ratio (52.75 to 53.25 mol%), of manganese-zinc ferrites containing a median zinc ratio of 18 and 19 mol%.

Good over-all magnetic performances were reported on the materials calculated on the basis of 52.75 and 53.00 mol% iron oxide with the 52.75 iron oxide ratio displaying some advantages: a higher μ_oQ-product, and a better stability of μ_o vs. temperature under varying firing conditions.

Upon these results, it was decided to initiate a new test series of similar compositions, but covering a slightly wider range of iron ratios and changing the preparation procedure by the introduction of calcined material of the same composition into the materials. This, in previous work, had resulted in improved μ_oQ-products.

In the new test series, MF-8632, the iron oxide ratio was varied from 52.5 to 53.5 mol% in steps of .25 mol%, and the zinc ratio was maintained constant at 18 mol%.

The composition of MF-8632 is (in mol%):

MF-8632	-1	-2	-3	-4	-5
Fe_2O_3	52.50	52.75	53.00	53.25	53.50
MnO	29.50	29.25	29.00	28.75	28.50
ZnO	18.00	18.00	18.00	18.00	18.00

Raw materials were of good commercial quality.

Each batch was compounded by 50% by weight of raw materials, as received, and 50% by weight of calcine of the same composition obtained by firing the materials in granulated form to approximately 2300°F in a production tunnel kiln on a cycle of 28 hours, in air.

The batches were wet ball-milled for 18 hours with the addition of an organic binder and spray-dried.

From these materials, toroids of approximately 25 mm O.D. (F-109) were pressed and complete sets of the whole series were subjected to firings at different peak temperatures.

The results obtained on three of these firings, to 2360°F, 2390°F and 2400°F, respectively, combined with cooling in nitrogen, were considered typical of the performance of the five materials comprising test series MF-8632 and are given in this report.

Values of μ_o, Q and μ_oQ, obtained 24 hours after demagnetization at frequencies from 50 to 400 kc/s are presented in Table 270, and the averaged μ_oQ-products of the same frequency range, as condensed from Table 270, are given in Table 271.

Values of μ_o vs. temperature (-65°C to +150°C) are given in Graphs 578 to 580. From the data presented, the following conclusions may be drawn:

Tables 270 and 271: with increasing iron ratios and in the frequency range of 50 and 100 kc/s, μ_oQ-products decrease. At the high frequencies, this trend appears to reverse itself, and the materials higher in iron ratio maintain a better performance of μ_oQ up to 400 kc/s.

Generally, test series MF-8632 containing 50% by weight of well pre-reacted calcines, resulted in noticeably improved μ_oQ values over previously described materials of similar compositions but not containing calcines.

Graphs 578 to 580: the change of $\Delta\mu_o/\mu_o$ vs. temperature with increasing iron ratios shows the familiar pattern depicted in previous reports. The temperature coefficient shows a similar trend of becoming irregular with iron ratios over 53.0 mol%, especially when combined with firing to higher peak temperatures.

Therefore, it appears that the introduction of calcines into the materials did not appreciably affect the change of μ_o vs. temperature, and that, as reported previously, the most consistently positive temperature coefficients are obtained with materials based on formulas calculated on the basis of slightly less than 53.0 mol% iron oxide.

In this connection, it is noted that all compositions given in the reports represent the composition of the materials as added to the steel mills, before grinding.

Because of abrasion occuring during milling, the iron ratio after grinding will be slightly higher. This gain in Fe was not determined for the purpose of this investigation.

PART II

PERMEABILITY OF MANGANESE-ZINC FERRITES IN THE TEMPERATURE RANGE -196°C TO +150°C

This is the first report on the performance of μ_o vs. temperature below -65°C. In order to cover a wide range of typical compositions of manganese-zinc ferrites in this initial work, the three test series, MF-8401, MF-8402 and MF 8400, comprising nine different materials were chosen for this investigation. Their compositions are:

	MF-8401			MF-8402			MF-8400		
MOL%	-1	-2	-3	-1	-2	-3	-1	-2	-3
Fe_2O_3	50	53	56	50	53	56	50	53	56
MnO	38	32	26	35	29	23	32	26	20
ZnO	12	15	18	15	18	21	18	21	24

The preparation of these materials and some magnetic data on μ_o, Q, $\mu_o Q$, $\Delta\mu_o/\mu_o\Delta T$, as well as on disaccommodation, have been given in Report No. 52 (1 June 1962 to 31 August 1962, pages 10-11, Tables 265 - 266).

Sample toroids, wound with thirty turns of #24 copper wire were enclosed in a thick-walled aluminum capsule which also contained an iron-constantan thermocouple for temperature measurement. A heating element - to obtain temperatures above room temperature - was placed into the bottom of a stainless steel Dewar flask. The aluminum capsule containing the samples and the thermocouple was suspended above the heating element in the Dewar flask. Liquid nitrogen, sufficient to cover the capsule completely, was poured into the flask.

The first measurements were taken after the temperature inside the capsule was safely established at the temperature of the liquid nitrogen. With the liquid nitrogen gradually vaporizing, a slowly rising temperature inside the capsule was obtained. After reaching room temperature, current was applied to the heating element and the temperature inside the flask gradually raised up to +150°C.

Measurements were taken at intervals of approximately 10°C, over the complete temperature range from -196°C to +150°C.

The results are recorded in Graphs 581 to 586. The following observations were made: all materials display a considerable decrease of permeability with decreasing temperature. In the vicinity of -196°C, only a small fraction of the permeability measured at room temperature remains.

All high iron-excess materials (56 mol% Fe_2O_3) display a characteristic peak at temperatures in the vicinity of -80°C and a valley in the region of 0°C ("camel-back curve"). This interesting phenomenon is probably due to the formation of $FeO \cdot Fe_2O_3$ and is less pronounced with the materials containing higher zinc ratios.

Slight irregularity of the permeability curve is also observed with some of the materials containing 53 mol% iron, especially when they were fired to the higher peak temperature.

The most regular performance of μ_0 within the temperatures of -196°C to +150°C is observed with the materials containing 50 mol% iron.

Further comments on this subject are reserved until more test data is on hand for evaluation.

PART III

DISACCOMMODATION (AGING) OF COMMERCIALLY PRODUCED FERRITES

This is the initial report on the investigation of aging over a period of several months, of various ferrites from the production of Indiana General Corp., Electronics Division.

The following materials were chosen and the following test methods used:

MATERIAL	FIRING	TEST FREQUENCY	TEST INSTRUMENT
*T-1 *O-3 **MF-4373-A, #5	Tunnel Kiln Protective Gas	100 Kc/s	General Radio R-F Reactance Bridge Type 916-AL
**MF-4373-A, #101	Batch Kiln Protective Gas	100 Kc/s	General Radio R-F Reactance Bridge Type 916-AL
***Q-1 ***Q-2 ***Q-3 ***MF-6835-3	Tunnel Kiln in Air	1 Mc/s 2 Mc/s 4 Mc/s 1 Mc/s	Boonton Q-Meter Type 260

NOTE:

- * Manganese-zinc ferrite, approximately 53 mol% Fe_2O_3.
- ** High iron-excess manganese-zinc ferrite, approximately 56 mol% Fe_2O_3.
- *** Nickel-zinc ferrites of various iron-excess ratios, plus additions.

Preliminary measurements had indicated that results obtained on large toroids of approximately 70mm o.d. (F-568) were in close agreement to results obtained on small toroids of approximately 25mm o.d. (F-109). For this reason and in order to limit this investigation to a practical number of test specimens, only small toroids were pressed from the above-named materials and fired in production kilns under regular production conditions.

The following test methods was used:

1. All samples were wound with 30 turns of #24 copper wire, uniformly distributed, and taped to individual phenolic boards with the leads secured to banana plugs. Values of μ_o and Q were measured and are presented in Table 272.

2. The samples were then demagnetized by a 60 cycle d.c. field of approximately 700 gauss, and the μ_o and Q were measured again one minute after demagnetization. These values are also given in Table 272.

The value of μ_o, obtained one minute after demagnetization was considered the reference permeability for the purpose of the aging test.

3. Subsequent measurements were made after 24 hours and at time intervals as indicated in Graphs 587, 588.

4. Samples were maintained at room temperature between measurements.

5. Percent change in μ_o was computed from: $\Delta\mu/\mu_o = \mu_o - \mu_T/\mu_o \times 100\%$.

6. Graphs were plotted using average values of % $\Delta\mu$ obtained from two toroids of each material.

As can be seen from Table 272, the values of μ_o measured one minute after demagnetization are generally higher than the ones obtained before demagnetization. This increase in permeability amounts to 4 to 5% with the "normal" manganese-zinc ferrites, rises to 13 and 14% with the high iron-oxide telecommunication materials, and reaches peak values of 19 to 28% with the Q-materials.

In approximate sequence to this gain of μ_o, but at a larger ratio, Q deteriorates under the same conditions.

Graphs 587 and 588, plotted on a semi-logarithmic scale, give the percent change of μ_o vs. time from two different firings under similar conditions of the same samples of materials. In these, the highest disaccommodation, 14 to 16%, is displayed by material MF-4373-A when fired in the tunnel kiln; the batch kiln firing of the same material resulting in a slightly lower figure.

The "normal" manganese-zinc ferrites T-1 and 0-3 show disaccommodation values from 5 to 8% when fired in the tunnel kiln. (The same materials fired in batch type kilns, show irregularites which need further investigation). Both types of materials, MF-4373-A and T-1, 0-3, after approximately 3 months show percent values of disaccommodation which correspond, roughly, to the percent $\Delta\mu$ gained by the demagnetization.

The nickel-zinc ferrites with additions over the period depicted in the graphs, show low disaccommodation values in approximate sequence with their iron-excess ratios. These materials, over a period of more than 3 months, have lost only a fraction of the μ_0 gained by the demagnetization, but at the same time their Q values remain far below their values prior to demagnetization. It should be remembered that these materials, unlike the manganese-zinc ferrites, initially have a constricted hysteresis loop.

PART IV

TEMPERATURE-STABLE MATERIAL IN THE 2-12 MC/S RANGE

In continuation of the work described in Report No. 52, Pages 14 and 15, Tables 267 and 268, Graphs 564 to 569, a new series of calcined material MF-6835-3 was prepared. The purpose of this was to study the combined effects of milling and firing on this material.

The preparation of the series was as follows: a large laboratory batch was wet-milled for 18 hours, dried, granulated and calcined at approximately 2300°F. Four batches from this calcine were then milled using a weight ratio of 10 (5/8" steel balls): 1 (calcine): 2 (water) for periods of 4, 8, 16 and 32 hours, respectively. After these millings the batches were dried, wet-milled with deflocculants and binders for 18 hours and spray-dried.

In previous work it was found that the intrinsic coercive force of ferrite powder could be related to its particle size. No attempt was made to correlate the coercive force with the actual particle size of the material in this present study, but measurements of the coercive force were taken to note the relative differences between the different millings. These measurements showed a linear increase from the 4 to the 32 hour milling; however, after the additional milling for spray-drying this was no longer the case; the 4 and 8 hour mills gave similar coercive force readings, the 16 hour mill a considerably higher one than the 4 or 8 hour mills, and the 32 hour mill slightly higher.

Samples from these batches were prepared in the usual manner and fired in various locations of a production tunnel kiln in air. Magnetic results of these firings are shown in Graphs 589 to 592 and Tables 272 and 273. Table 273 shows the average grain size (obtained by microscope), density and porosity (obtained by water absorption) of the samples from these firings.

Under the same firing conditions the material with the finest powder particle size (highest coercive force reading) matured at a lower temperature, but developed larger average grain sise and showed a tendency toward preferential grain growth, that is, inhomogeneous grain sizes.

From the results, it appears that the best $\mu_0 Q$-products are obtained when the material has small, homogeneous grains combined with high density. The best temperature coefficients, however, are obtained when the material has small, homogeneous grains combined with high porosity. By controlling the milling and thus the powder particle size and then firing to a temperature to promote a homogeneous grain size between 2 and 3 microns, combined with a porosity between

3 and 5 percent water absorption by weight, material MF-6835-3 can be prepared to give good $\mu_0 Q$ values and a temperature coefficient of 200 ppm/°C or less. Initial attempts to further lower the temperature coefficient by raising the porosity through lower firing in a laboratory kiln have been unsuccessful, but further study along this line is intended.

PART V

ZERO-FIELD FERRITES IN THE 50-480 MC/S RANGE

Following the line of reasoning suggested in Report No. 52, page 16, Curie points were determined for samples of the series $NiO_{(1-x-y)}CoO_xZnO_yFe_2O_{3(t)}$ with iron oxide content from 1.30 to 1.50 mols and an attempt was made to improve the μ_o vs. temperature behavior of these materials by annealing closer to the Curie point. Curie points for these materials were found to lie in the range 590°C to 635°C. As the annealing temperature approached the Curie point, however, the Q values of the samples, measured at 200 mc/s, became progressively lower. Specimens annealed at 400°C showed a maximum Q value of 69, after annealing at a temperature of 480°C a maximum Q value of 29, and finally after annealing at a temperature of 550°C the Q values were less than 5. In consequence of the sharp losses of Q values the procedure was deemed of no practical value and no attempt was made to measure the dependence of μ_o versus temperature.

The second suggested line of study in Report No. 52, page 16, was the area beyond an iron oxide content of 1.5 mols. Although peak performance of the series occurs at an iron oxide content of 1.25 to 1.30 mols, there is no clear, unequivocal deterioration of magnetic parameters with iron oxide content varying from 1.30 to 1.50 mols. Accordingly, a series was prepared extending the iron oxide content in increments of .25 mols from 1.50 to 2.50 mols. The first material in this series with Fe_2O_3 content of 1.75 mols resulted in maximum μ_oQ-products of 250. At higher Fe_2O_3 content the μ_oQ-products were less than 150. These materials were considered to be of no practical value.

All measurements were taken at room temperature.

This concludes the evaluation of the series $NiO_{(1-x-y)}CoO_xZnO_yFe_2O_{3(t)}$. The salient features of this series are the following - the highest values of μ_o, Q and μ_oQ-product measured at 200 mc/s are obtained with an iron content of 1.25-1.30 mols. It should be noted, however, that useful products can be obtained throughout the region of iron oxide content from 1.10 to 1.45 mols. Increasing the Fe_2O_3 content will make the slope of the μ_o vs. temperature curve more unidirectional, but it will also make the slope steeper.

PART VI

RESEARCH PLANNED FOR NEXT QUARTER

1. Based on compositions near the range of 53 mol% Fe_2O_3, the effect of grain size as obtained by different calcining and firing techniques will be studied.

2. The studyof disaccommodation ferrites will be continued and will include experimental materials.

3. The study of the μ_o versus temperature behavior of some experimental and commercially produced ferrites in the temperature range -196°C to +150°C will be continued. Low temperature measurements of the resistivities of these materials will be made.

4. In the 2-12 Mc/s range, further study will be given to the preparation and firing of material MF-6835-3 in an attempt to further lower the temperature coefficient of μ_o.

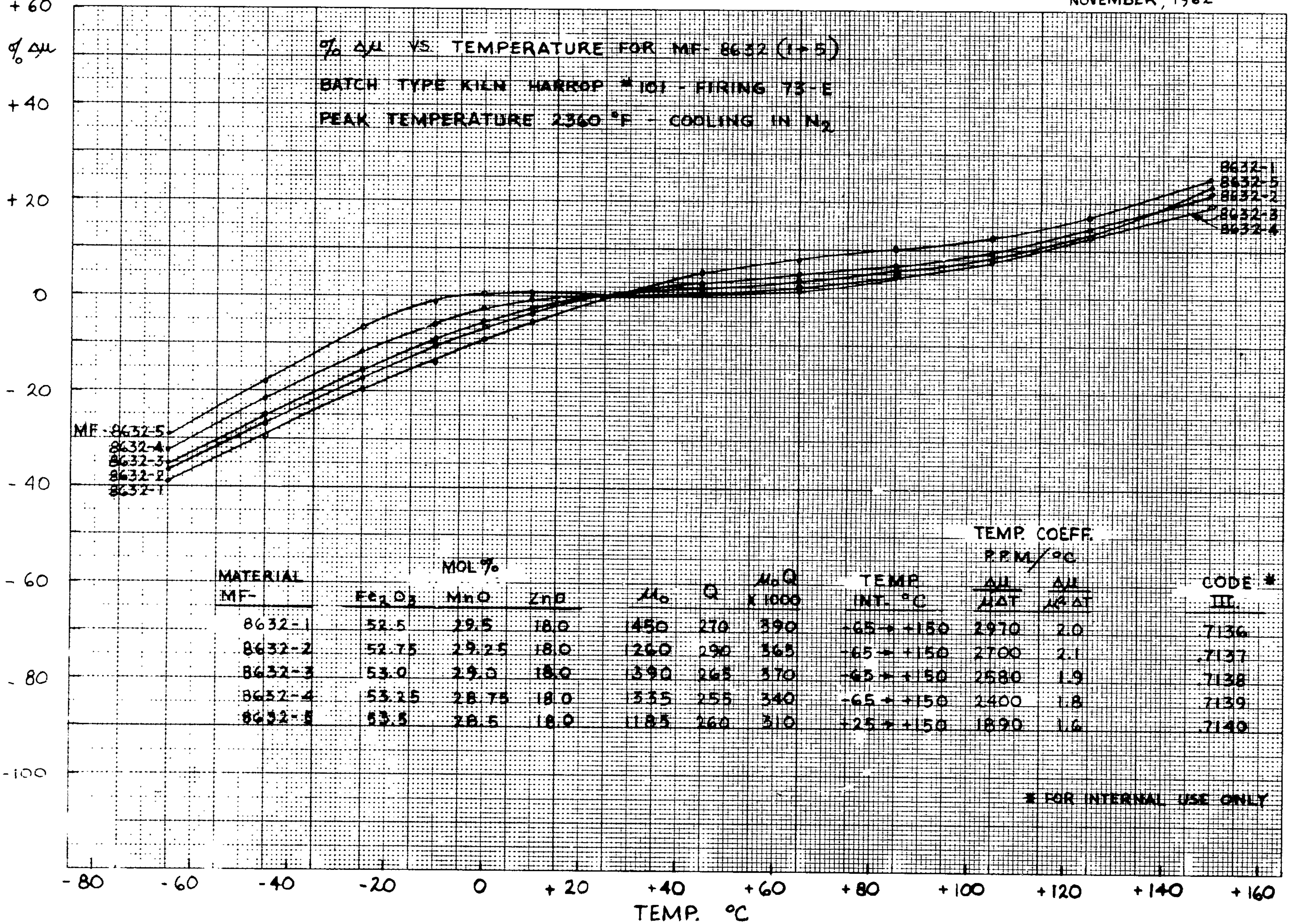
PART VII

MANHOURS SPENT ON CONTRACT FOR THE PERIOD 1 September 1962 to 30 November 1962

NAME	TITLE	HOURS
K. Wetzel	Chemist	396
E.Schwabe	Physicist	128
M. Eisenberg	Project Engineer	78
S. Golian	Ceramic Engineer	103-1/2
D. Sullivan	Ceramic Engineer	400
K. Sivak	Chemist	10
C. Cooper	Technician	35
P. Dacey	Technician	21
E. Hozeny	Technician	53
D. Kinsley	Technician	39
E. Szatkowski	Technician	440
G. Lee	Technician	472
M. Zudonyi	Technician	24
S. Rubarski	Laboratory Assistant	44-1/2

GRAPH 578

NOVEMBER, 1962

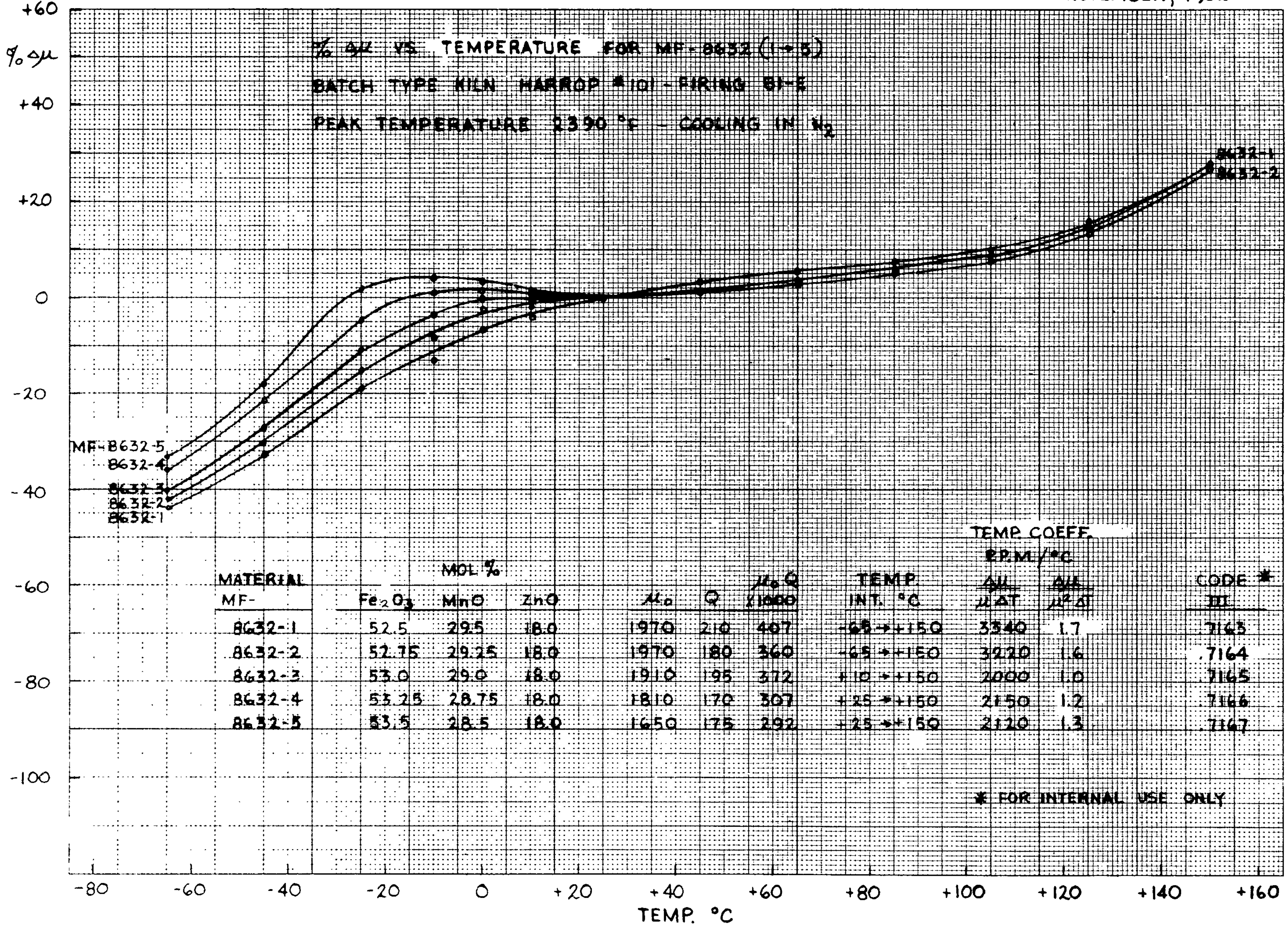


MATERIAL MF-	MOL % Fe_2O_3	MOL % MnO	MOL % ZnO	μ_o	Q	$\mu_o Q$ X 1000	TEMP. INT. °C	TEMP. COEFF. P.P.M./°C $\frac{\Delta\mu}{\mu \Delta T}$	TEMP. COEFF. P.P.M./°C $\frac{\Delta\mu}{\mu^2 \Delta T}$	CODE * III.
8632-1	52.5	29.5	18.0	1450	270	390	-65 → +150	2970	2.0	.7136
8632-2	52.75	29.25	18.0	1260	290	365	-65 → +150	2700	2.1	.7137
8632-3	53.0	29.0	18.0	1390	265	370	-65 → +150	2580	1.9	.7138
8632-4	53.25	28.75	18.0	1335	255	340	-65 → +150	2400	1.8	.7139
8632-5	53.5	28.5	18.0	1185	260	310	+25 → +150	1890	1.6	.7140

* FOR INTERNAL USE ONLY

GRAPH 579

NOVEMBER, 1962

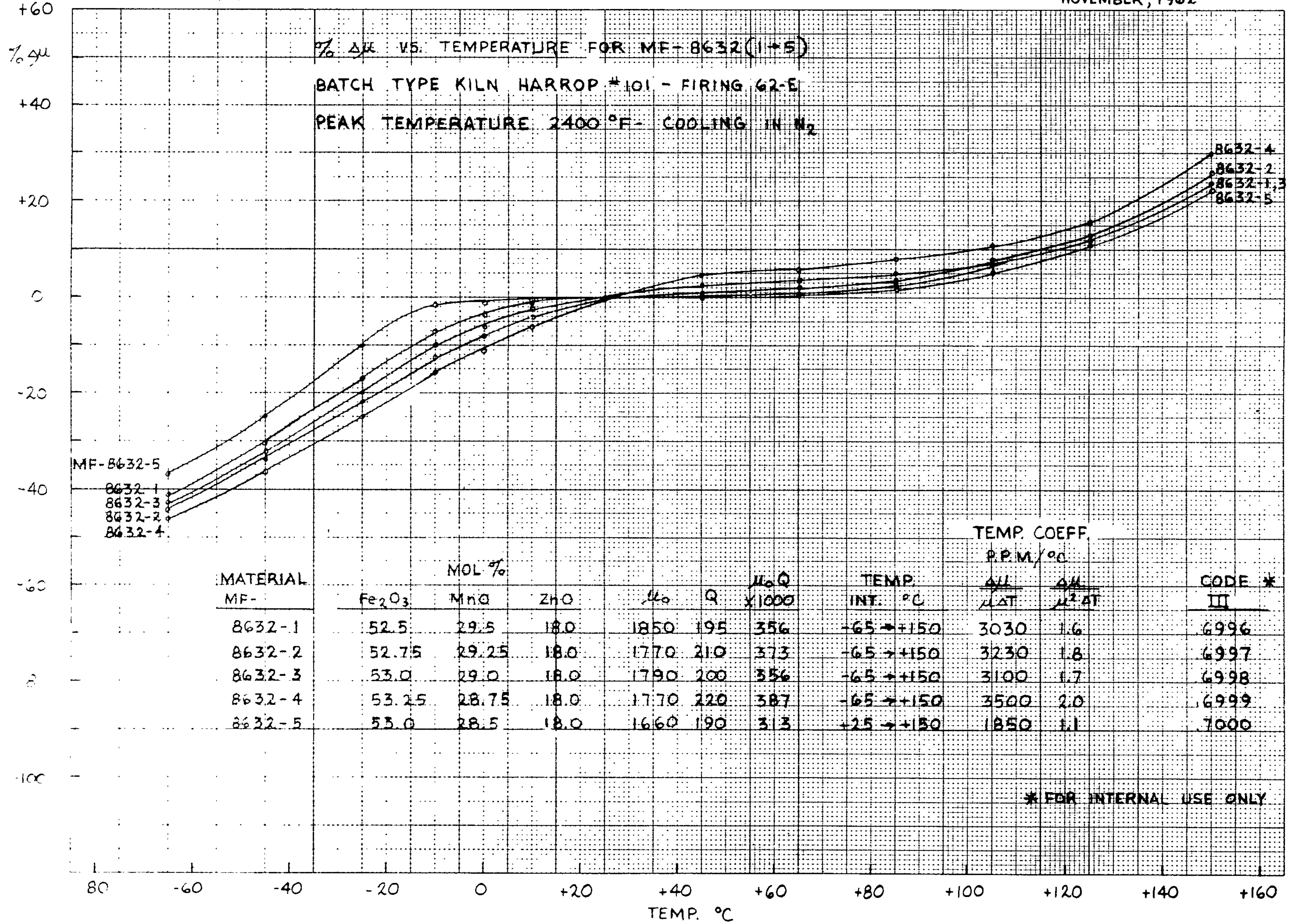


MATERIAL MF-	MOL % Fe_2O_3	MnO	ZnO	μ_o	Q	$\mu_o Q$ / 1000	TEMP. INT. °C	TEMP. COEFF. P.P.M./°C $\frac{\Delta\mu}{\mu\Delta T}$	$\frac{\Delta\mu}{\mu^2\Delta T}$	CODE * III
8632-1	52.5	29.5	18.0	1970	210	407	-65 → +150	3340	1.7	7163
8632-2	52.75	29.25	18.0	1970	180	360	-65 → +150	3220	1.6	7164
8632-3	53.0	29.0	18.0	1910	195	372	+10 → +150	2000	1.0	7165
8632-4	53.25	28.75	18.0	1810	170	307	+25 → +150	2150	1.2	7166
8632-5	53.5	28.5	18.0	1650	175	292	+25 → +150	2120	1.3	7167

* FOR INTERNAL USE ONLY

GRAPH 580

NOVEMBER, 1962

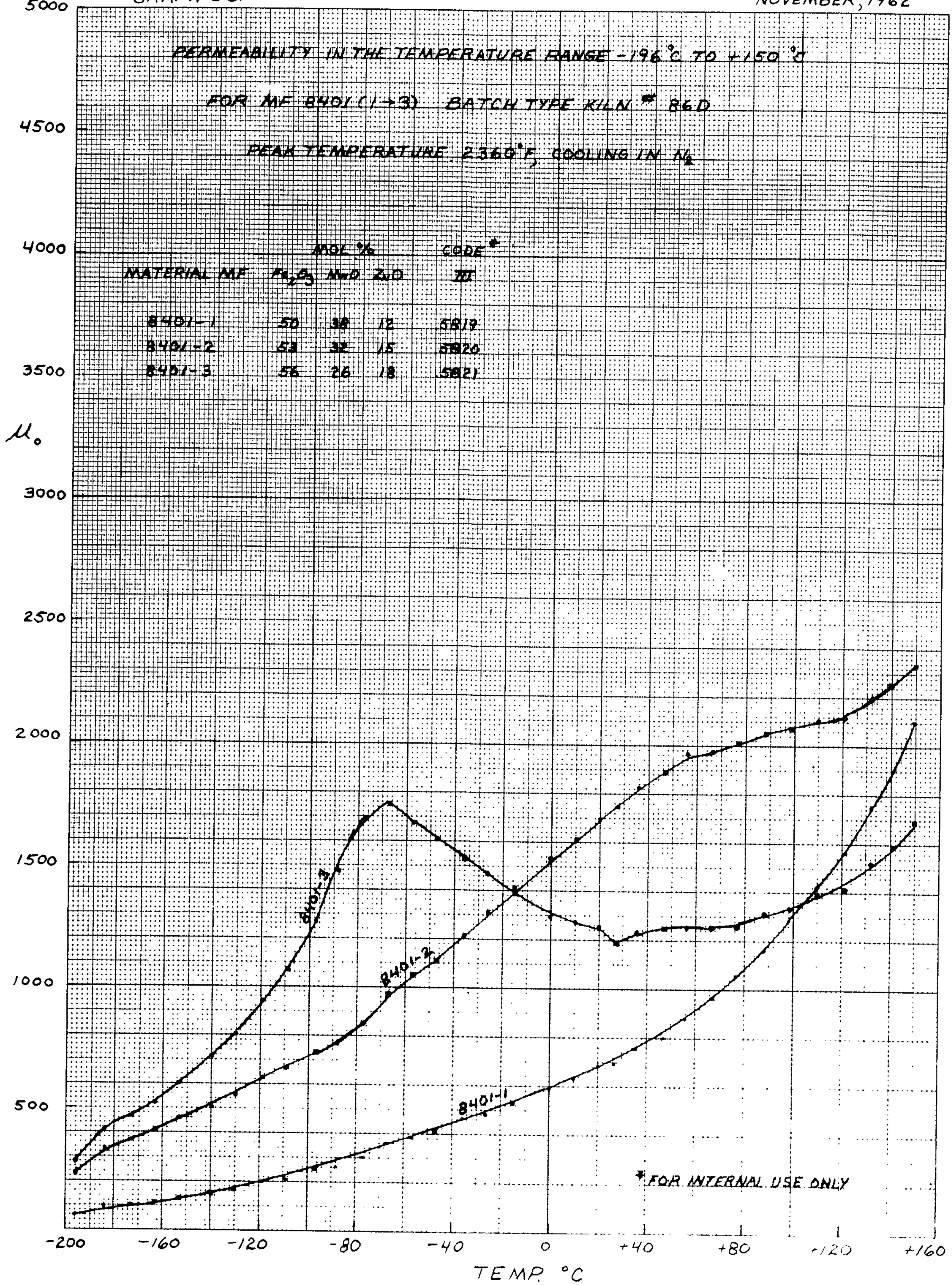


MATERIAL MF-	MOL % Fe_2O_3	MOL % MnO	MOL % ZnO	μ_o	Q	$\mu_o Q$ x1000	TEMP. INT. °C	TEMP. COEFF. P.P.M./°C $\frac{\Delta\mu}{\mu \Delta T}$	TEMP. COEFF. P.P.M./°C $\frac{\Delta\mu}{\mu^2 \Delta T}$	CODE * III
8632-1	52.5	29.5	18.0	1850	195	356	-65 → +150	3030	1.6	6996
8632-2	52.75	29.25	18.0	1770	210	373	-65 → +150	3230	1.8	6997
8632-3	53.0	29.0	18.0	1790	200	356	-65 → +150	3100	1.7	6998
8632-4	53.25	28.75	18.0	1770	220	387	-65 → +150	3500	2.0	6999
8632-5	53.0	28.5	18.0	1660	190	313	+25 → +150	1850	1.1	7000

* FOR INTERNAL USE ONLY

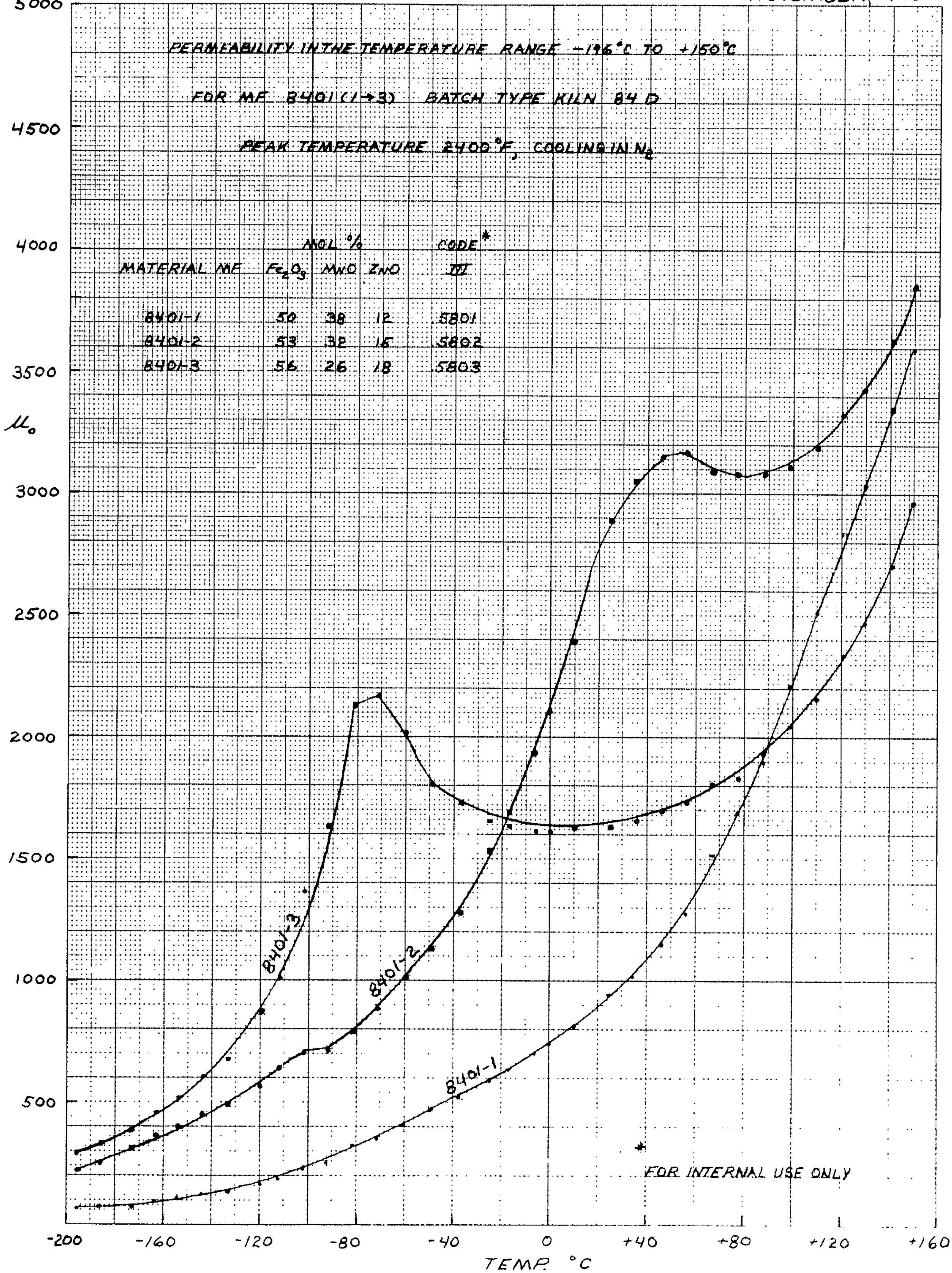
GRAPH 581

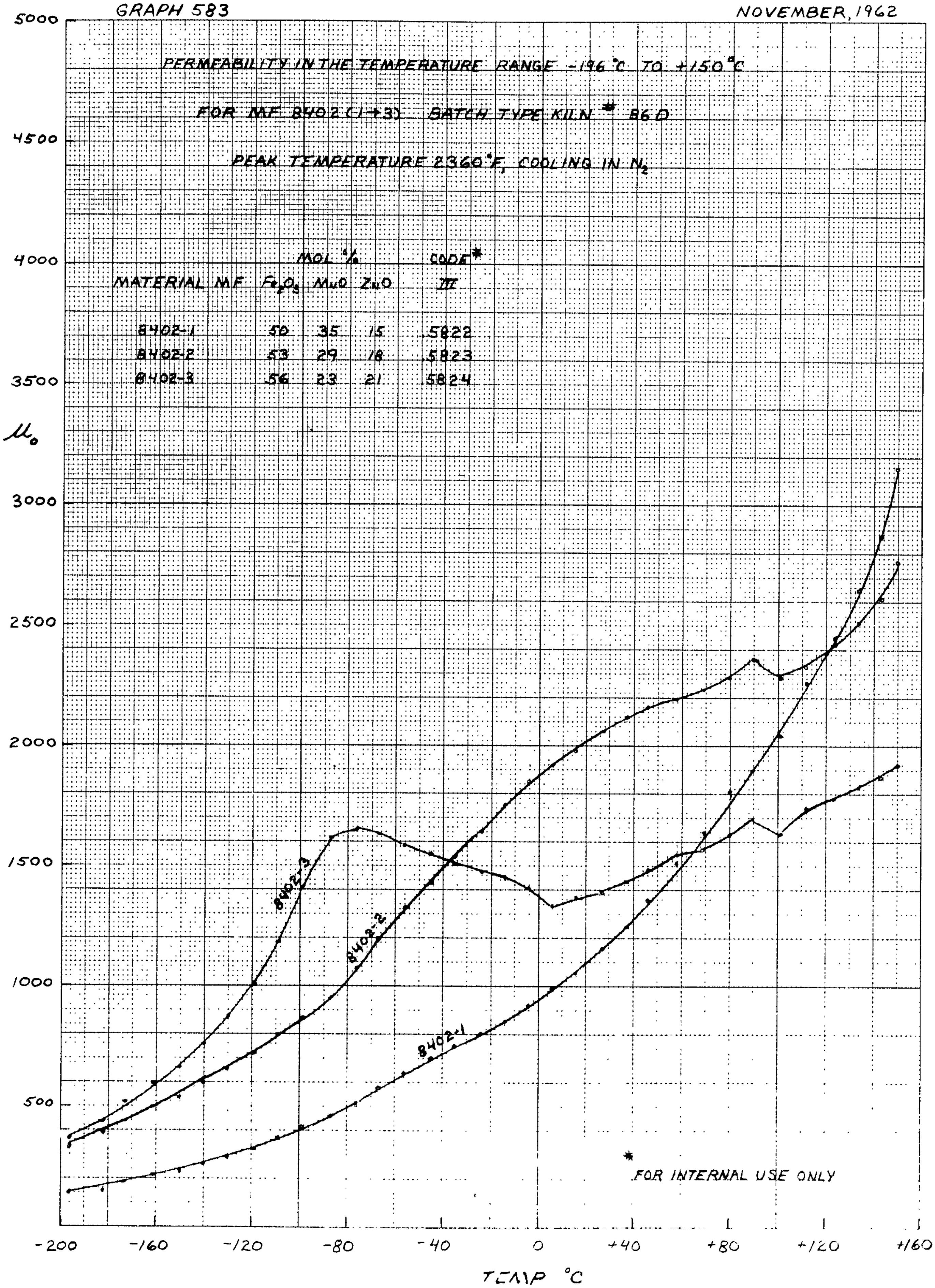
NOVEMBER, 1962



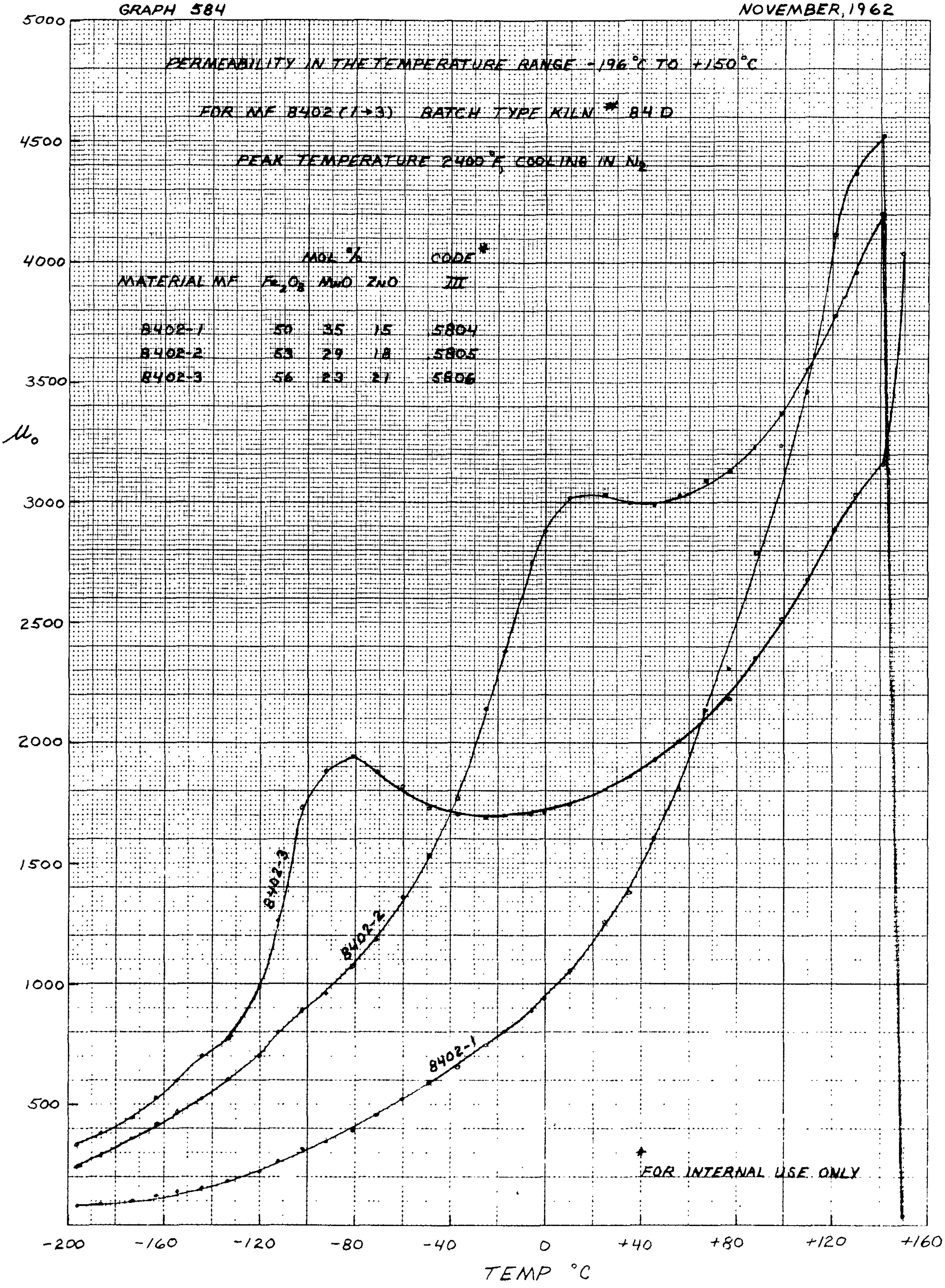
GRAPH 582

NOVEMBER, 1962

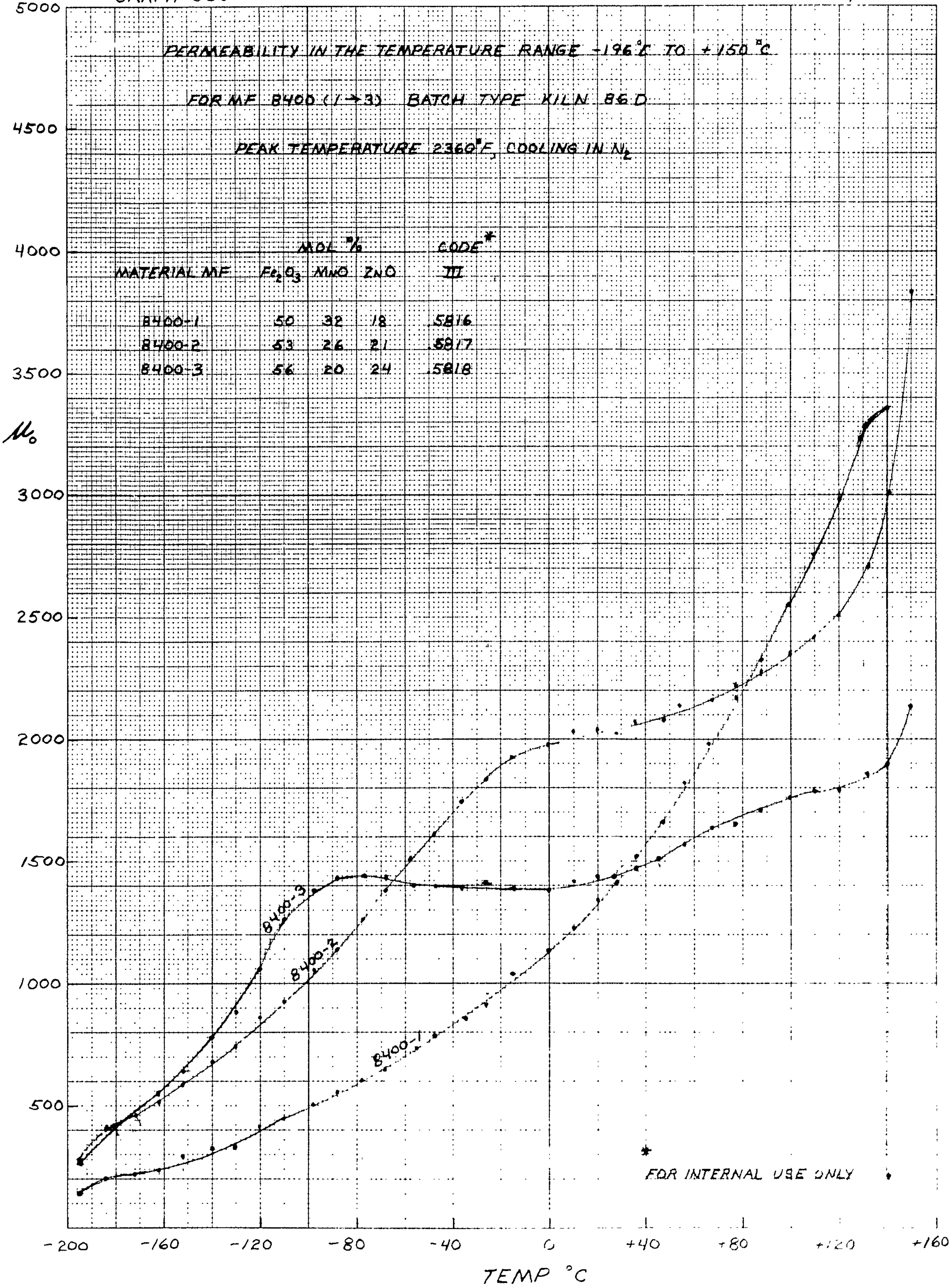




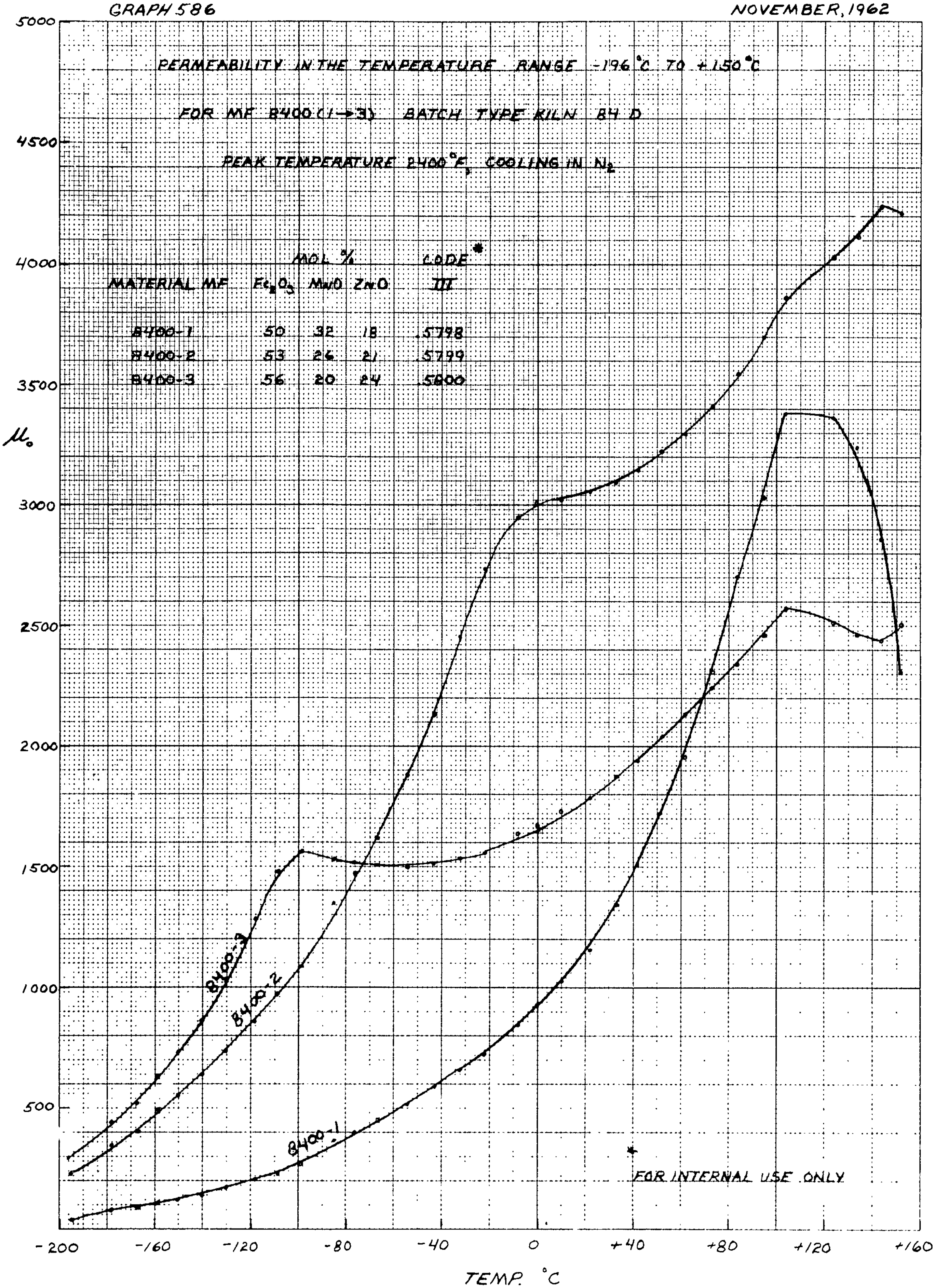
GRAPH 583
NOVEMBER, 1962
PERMEABILITY IN THE TEMPERATURE RANGE -196°C TO +150°C
FOR MF 8402 (1→3) BATCH TYPE KILN * 86 D
PEAK TEMPERATURE 2360°F, COOLING IN N2
MOL %
CODE*
MATERIAL MF Fe2O3 MnO ZnO
8402-1 50 35 15 .5822
8402-2 53 29 18 .5823
8402-3 56 23 21 .5824
μo
8402-3
8402-2
8402-1
* FOR INTERNAL USE ONLY
TEMP °C
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
-200
-160
-120
-80
-40
0
+40
+80
+120
+160

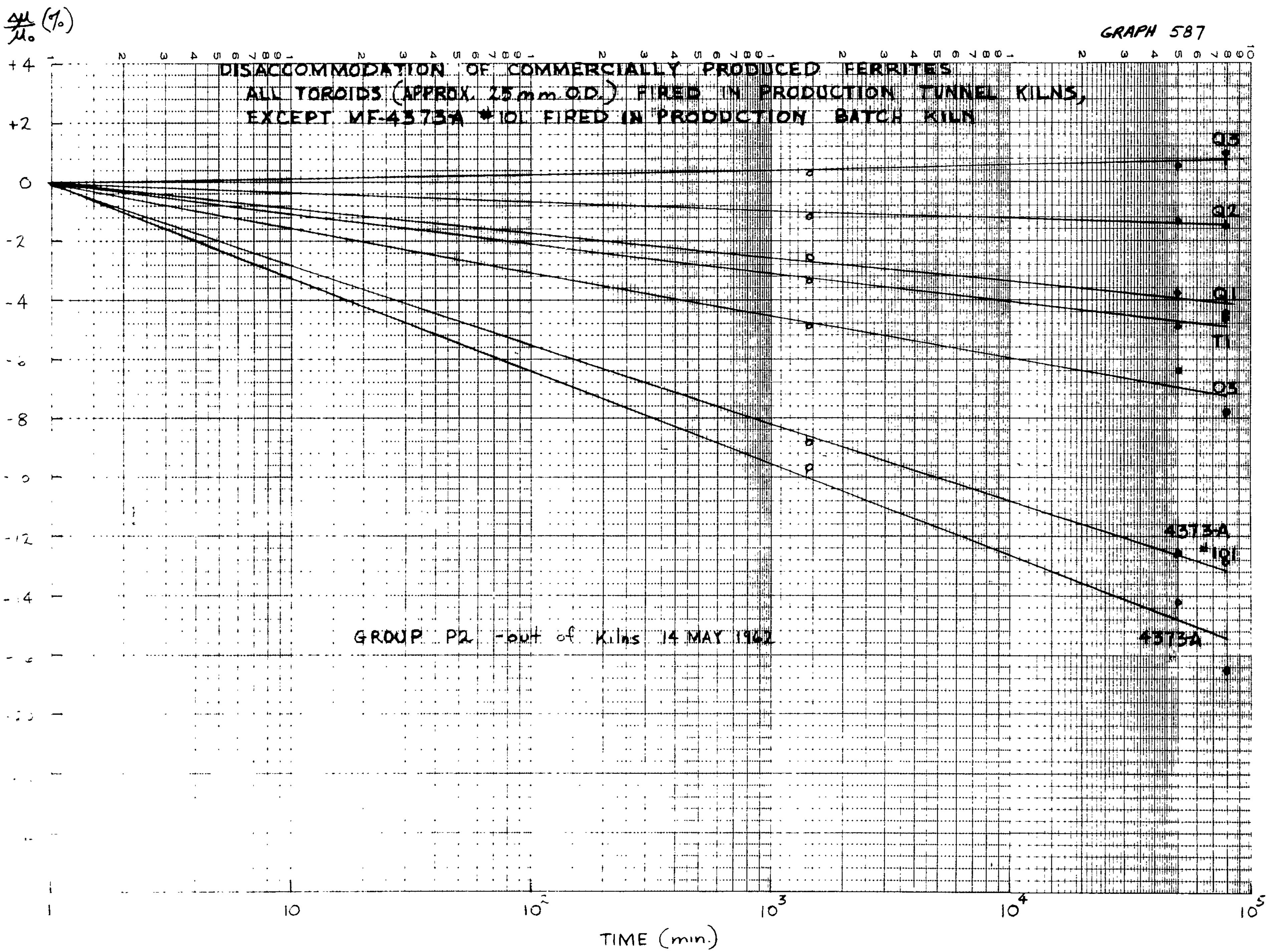

GRAPH 584
NOVEMBER, 1962
PERMEABILITY IN THE TEMPERATURE RANGE -196°C TO +150°C
FOR MF 8402 (1→3) BATCH TYPE KILN # 84 D
PEAK TEMPERATURE 2400°F, COOLING IN N2
MOL %
CODE #
MATERIAL MF Fe2O3 MnO ZnO III
8402-1 50 35 15 .5804
8402-2 53 29 18 .5805
8402-3 56 23 21 .5806
μo
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
8402-3
8402-2
8402-1
FOR INTERNAL USE ONLY
-200
-160
-120
-80
-40
0
+40
+80
+120
+160
TEMP °C

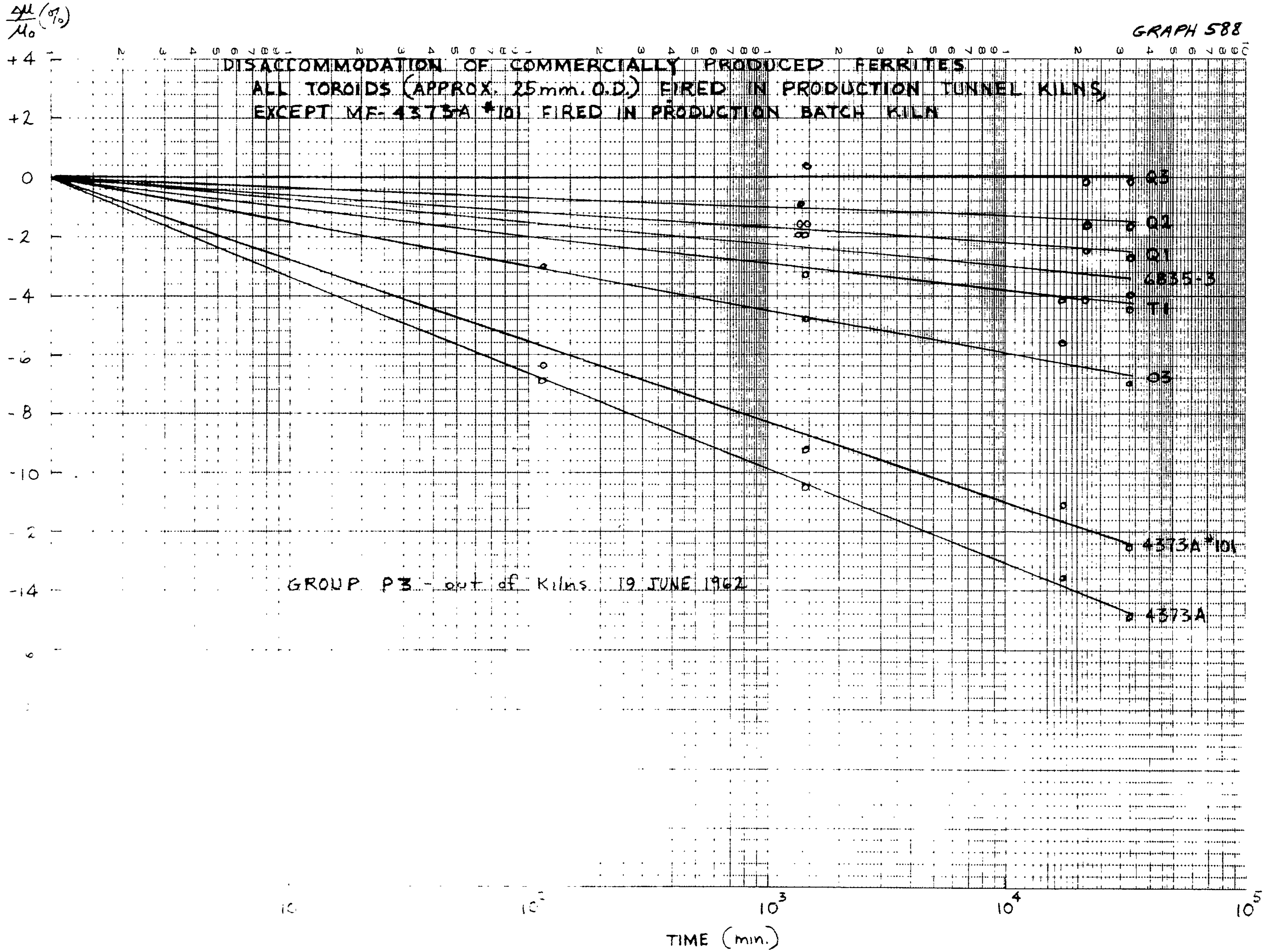
GRAPH 585 NOVEMBER, 1962



GRAPH 586 NOVEMBER, 1962

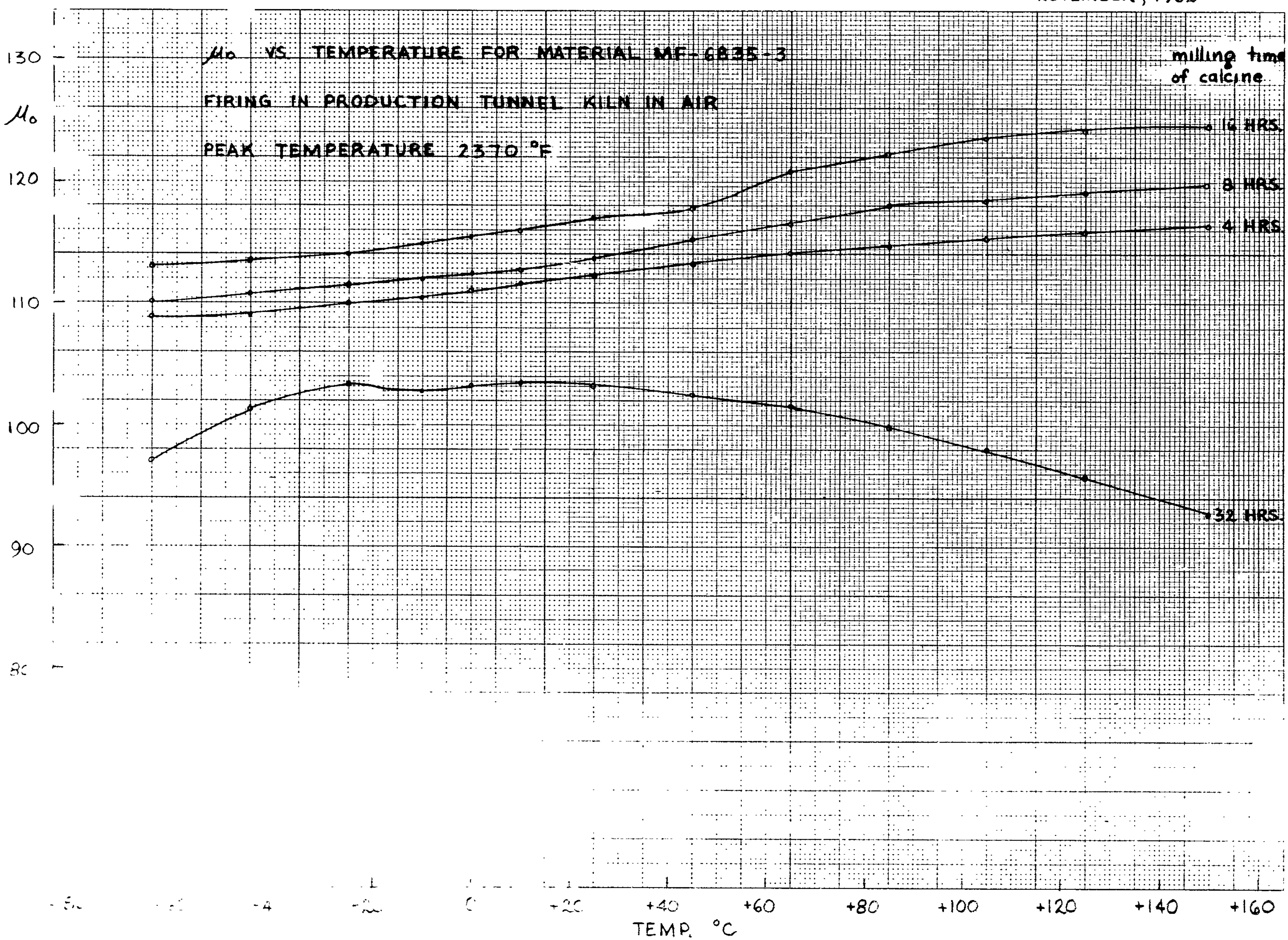



GRAPH 587
DISACCOMMODATION OF COMMERCIALLY PRODUCED FERRITES
ALL TOROIDS (APPROX. 25 mm O.D.) FIRED IN PRODUCTION TUNNEL KILNS,
EXCEPT MF-4373A #101 FIRED IN PRODUCTION BATCH KILN
Δμ/μ₀ (%)
+4
+2
0
-2
-4
-8
-12
Q3
Q2
Q1
T1
Q5
4373-A #101
4373A
GROUP P2 -out of Kilns 14 MAY 1962
1
10
10²
10³
10⁴
10⁵
TIME (min.)


DISACCOMMODATION OF COMMERCIALLY PRODUCED FERRITES
ALL TOROIDS (APPROX. 25mm. O.D.) FIRED IN PRODUCTION TUNNEL KILNS,
EXCEPT MF-4373A #101 FIRED IN PRODUCTION BATCH KILN
$\frac{\Delta\mu}{\mu_0}$ (%)
+4
+2
0
-2
-4
-6
-8
-10
-12
-14
Q3
Q2
Q1
6835-3
T1
O3
4373A #101
4373A
GROUP P3 - out of Kilns 19 JUNE 1962
10
10^2
10^3
10^4
10^5
TIME (min.)

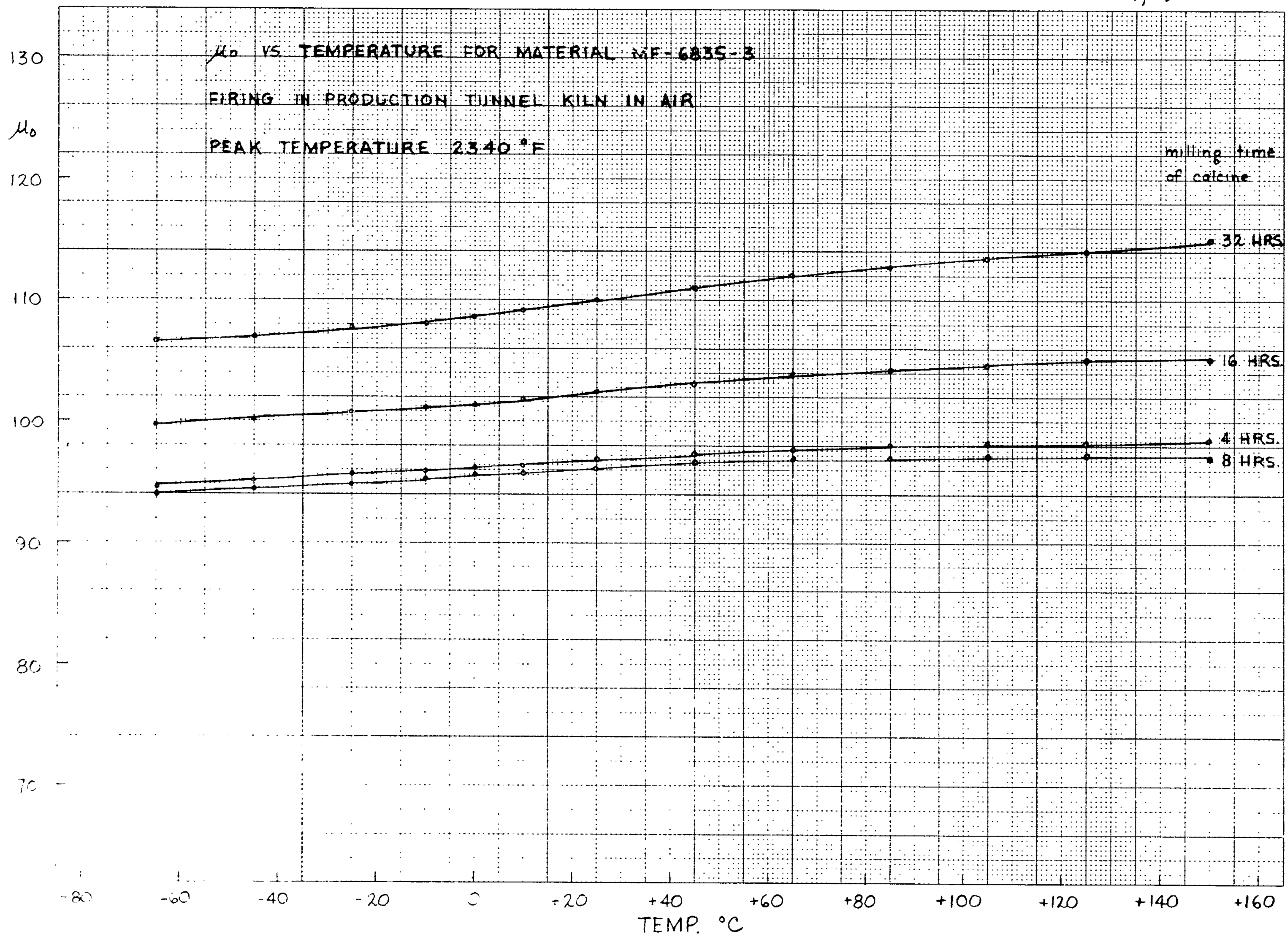
GRAPH 589

NOVEMBER, 1962



GRAPH 590

NOVEMBER, 1962



GRAPH 591

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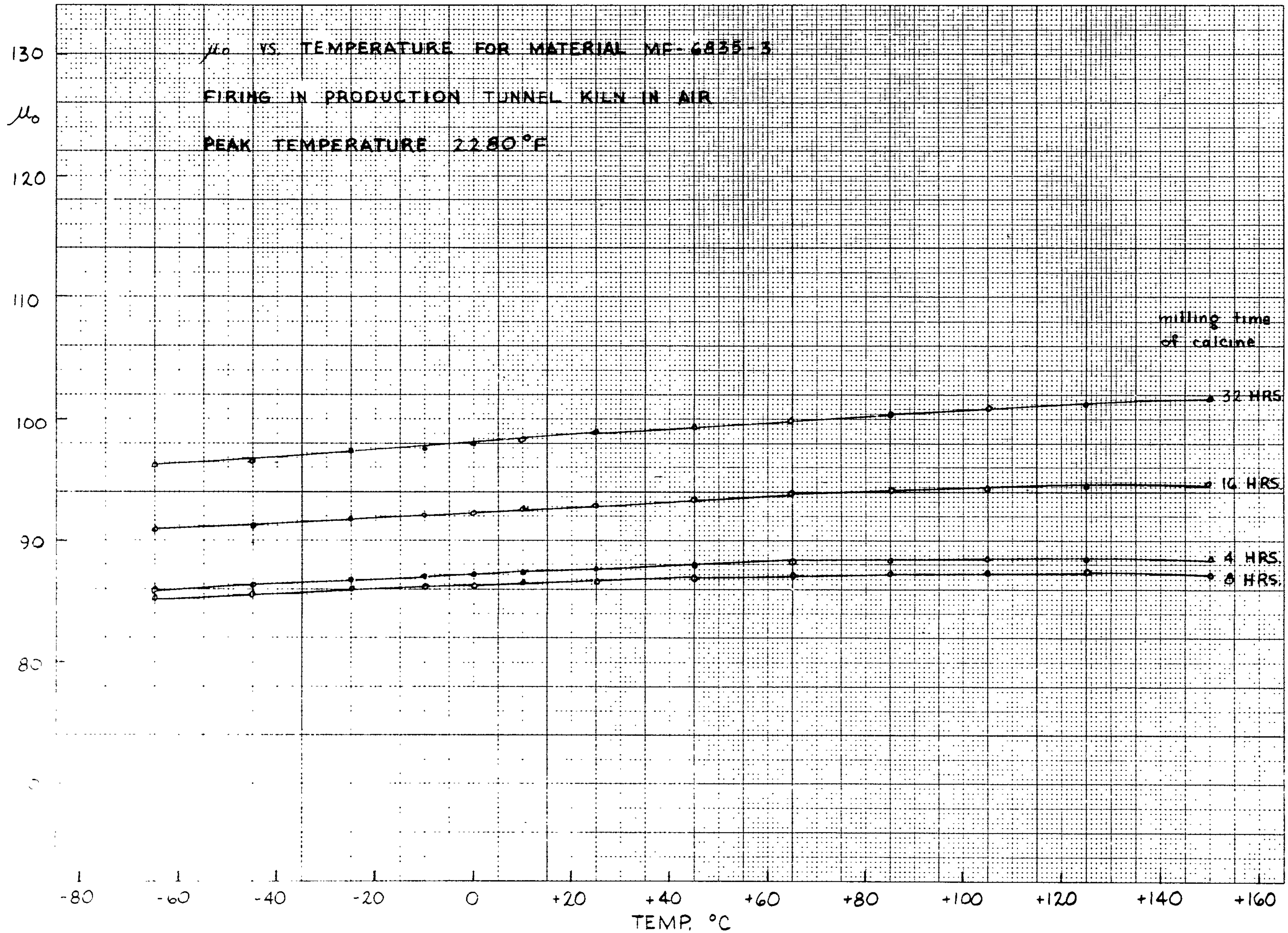

GRAPH 592

NOVEMBER, 1962

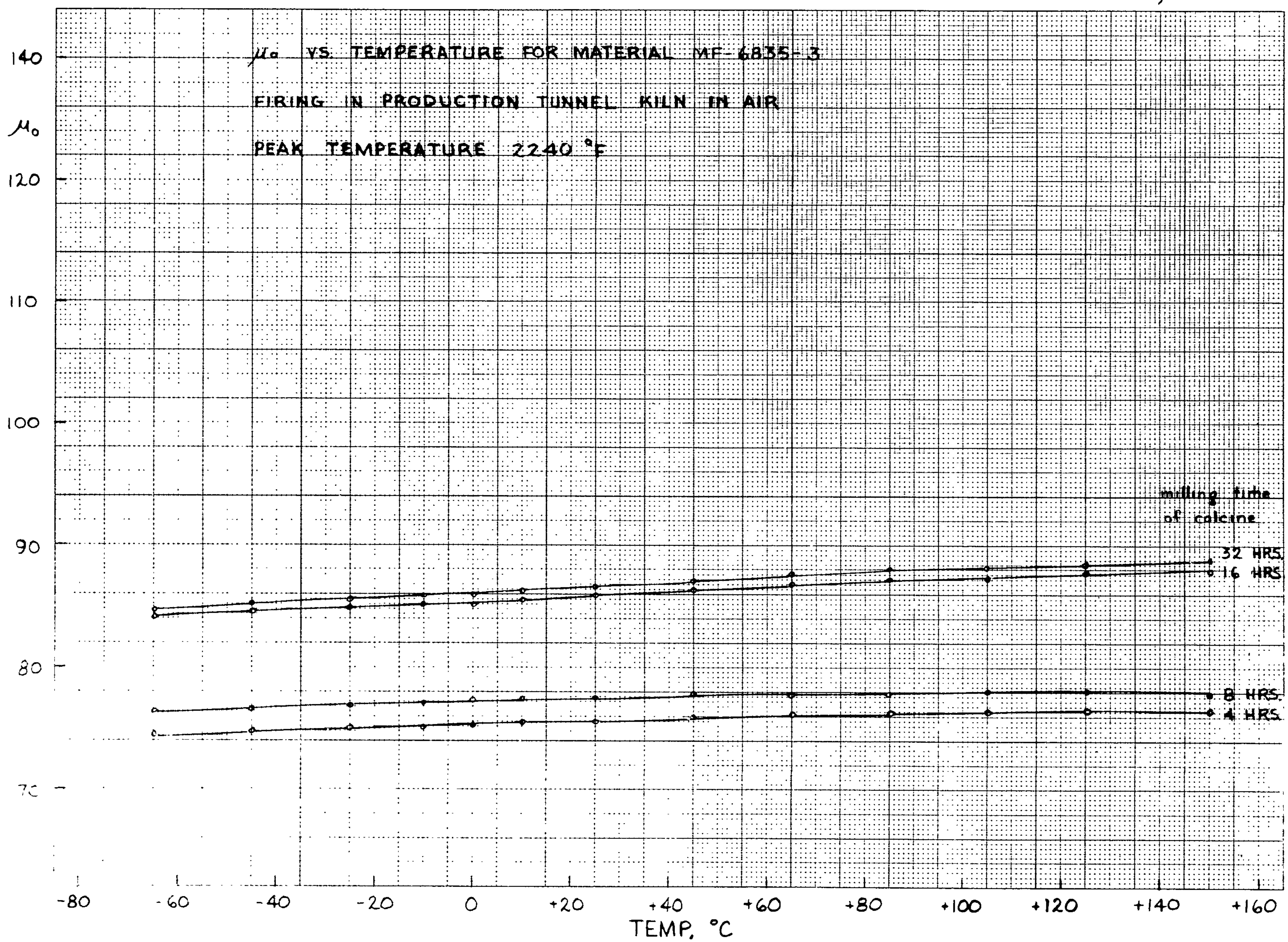

TABLE 270

MAGNETIC PROPERTIES OF MF-8632 (1-5) OBTAINED FROM THREE DIFFERENT FIRINGS MEASUREMENTS OF μ_o AND Q AT FREQUENCIES OF FROM 50 TO 400 KC/S 24 HRS. AFTER DEMAGNETIZATION

MF-8632	FIRING PEAK TEMP °F	50 KC/S μ_o	50 KC/S Q	50 KC/S x10^3	100 KC/S μ_o	100 KC/S Q	100 KC/S x10^3	200 KC/S μ_o	200 KC/S Q	200 KC/S x10^3	300 KC/S μ_o	300 KC/S Q	300 KC/S x10^3	400 KC/S μ_o	400 KC/S Q	400 KC/S x10^3	CODE No. III
-1	2360	1510	295	445	1490	280	415	1520	170	260	1550	100	155	1590	45	75	.7136
-1	2390	2020	260	525	2020	205	410	2050	105	215	2130	40	85	2190	15	35	.7163
-1	2400	1910	270	515	1890	200	380	1920	125	240	1980	75	150	2050	40	82	.6996
-2	2360	1280	340	435	1280	280	360	1300	185	240	1330	180	240	1350	60	80	.7137
-2	2390	2020	250	505	2030	185	380	2060	110	225	2140	50	110	2180	25	55	.7164
-2	2400	1830	290	530	1810	220	400	1840	125	230	1900	65	125	1980	25	50	.6997
-3	2360	1390	345	480	1410	295	415	1450	180	260	1470	120	175	1510	65	100	.7138
-3	2390	1970	260	510	1980	185	370	2010	105	210	2080	60	125	2150	25	55	.7165
-3	2400	1860	235	435	1840	210	380	1870	125	235	1930	70	135	2010	30	60	.6998
-4	2360	1370	315	430	1370	290	400	1400	180	250	1410	130	185	1440	85	125	.7139
-4	2390	1890	230	435	1890	175	330	1920	115	220	1980	65	130	2040	40	80	.7166
-4	2400	1830	260	475	1810	225	400	1840	120	220	1900	50	95	1960	25	50	.6999
-5	2360	1210	370	450	1230	270	330	1240	270	335	1250	130	160	1260	90	115	.7140
-5	2390	1740	245	425	1740	185	320	1770	195	130	1800	75	135	1850	50	95	.7167
-5	2400	1750	270	470	1730	195	340	1750	125	220	1790	85	150	1840	55	100	.7000

Measured on General Radio Bridge 916-AL

* These code numbers are for identification and internal use only.

TABLE 271

$\mu_o Q$-PRODUCTS OF MF-8632 AT FREQUENCIES FROM 50 TO 400 KC/S
AVERAGE FROM THREE DIFFERENT FIRINGS
(CONDENSED FROM TABLE 270)

MATERIAL MF-8632	COMPOSITION (MOL%) Fe_2O_3	MnO	ZnO	(24 HOURS AFTER DEMAGNETIZATION) $\mu_o Q \times 10^3$ 50kc/s	100kc/s	200kc/s	300kc/s	400kc/s
-1	52.5	29.5	18.0	495	400	240	130	65
-2	52.75	29.25	18.0	490	380	230	160	60
-3	53.0	29.0	18.0	475	400	235	145	70
-4	53.25	28.75	18.0	450	375	230	135	85
-5	53.5	28.5	18.0	450	330	230	150	100

TABLE 272

μ_o AND Q OF COMMERCIALLY PRODUCED FERRITES - BEFORE, AND ONE MINUTE AFTER DEMAGNETIZATION

Values averaged from two firings, under similar conditions, of the same materials.

Reference: Part III, Pages 11 to 13.

MATERIAL	T-1	0-3	4373-A	4373-A	Q-1	Q-2	Q-3	6335-3
Firing:	TUNNEL-	KILN		BATCH KILN	TUNNEL-KILN			
Atmosphere:	PROTECTIVE --	GAS			AIR	AIR	AIR	AIR
μ_o Before Demag.	1455	1328	1057	813	126.5	46.3	10.6	95
One minute after demag.	1513	1393	1194	928	153.5	55.8	12.6	122
% $\Delta\mu$	+4.0	+5.0	+12.9	+14.1	+21.3	+20.5	+19.0	+28.5
Q Before Demag.	77	82	183	366	341	460	265	214
One minute after demag.	70	72	135	230	186	270	222	128
% ΔQ	-9.1	-11.8	-26	-37.1	-45.4	-41.3	-16.2	-40.2

TABLE 273

MAGNETIC PROPERTIES OF MATERIAL MF-6835-3
OBTAINED FROM FOUR DIFFERENT MILLINGS AND
FROM FOUR DIFFERENT FIRINGS
IN PRODUCTION TUNNEL KILN IN AIR - CYCLE 28 HRS.

COMPOSITION	MOL %
Fe_2O_3	60.0
MnO	2.0
NiO	23.0
ZnO	15.0
Addition cobalt oxide (wgt.%)	0.25

CODE X1 .2	MILLING TIME OF CALCINE (HOURS)	PEAK TEMP °F	μ_o 5mc	μ_o 10mc	Q 5mc	Q 10mc	$\mu_o Q$ 5mc	$\mu_o Q$ 10mc	$\frac{\mu_o Q(10mc)}{\mu_o Q(5mc)}$	INTERVAL °C	TEMP. COEFF. (+ppm/°C) $\frac{\Delta\mu}{\mu\Delta T}$	TEMP. COEFF. (+ppm/°C) $\frac{\Delta\mu}{\mu^2\Delta T}$
551	4	2370	109	119	182	81	19,800	9,600	.485	-65→150	+314	+2.8
549	8		113	123	168	70	19,000	8,600	.453	-65→150	+390	+3.4
555	16		116	127	136	44	15,800	5,800	.354	-65→150	+456	+3.9
553	32		101	111	74	22	7,500	2,400	.320	+10→150	-831	-8.0
559	4	2340	95	100	210	128	20,000	12,800	.640	-65→150	+190	+2.0
557	8		94	101	208	120	19,600	12,100	.617	-65→125	+180	+1.9
563	16		99	106	202	118	20,000	12,500	.625	-65→150	+246	+2.4
561	32		106	114	174	80	18,400	9,100	.495	-65→150	+348	+3.2
543	4	2280	85	88	186	116	15,800	10,200	.646	-65→105	+176	+2.0
541	8		84	88	196	124	16,500	10,900	.661	-65→125	+141	+1.6
547	16		90	94	192	116	17,300	10,900	.630	-65→150	+192	+2.1
545	32		96	100	178	98	17,100	9,800	.573	-65→150	+249	+2.5
567	4	2240	73	76	198	140	14,500	10,600	.731	-65→105	+148	+2.0
565	8		75	77	204	146	15,300	11,200	.732	-65→125	+123	+1.6
571	16		83	86	204	140	16,900	12,000	.710	-65→150	+210	+2.4
569	32		83	86	204	140	16,900	12,000	.710	-65→150	+225	+2.6

TABLE 274

PHYSICAL PROPERTIES OF TOROIDS OF MATERIAL MF-6835-3

MILLING TIME OF CALCINE (HOURS)	FIRING PRODUCTION TUNNEL KILN PEAK TEMPERATURE	AVERAGE GRAIN SIZE (MICRONS)	DENSITY (g/cc)	POROSITY ABSORPTION OF WATER BY WEIGHT (%)
4	2370°F	3.3	4.5	2.1
8	2370°F	3.3	4.6	1.7
16	2370°F	4.3	4.7	1.1
32	2370°F	7.8	4.8	0.5
4	2340°F	2.6	4.3	3.5
8	2340°F	2.8	4.4	3.1
16	2340°F	3.0	4.5	2.1
32	2340°F	3.4	4.6	1.5
4	2280°F	2.70	4.2	4.3
8	2280°F	2.6	4.2	4.0
16	2280°F	2.8	4.3	3.1
32	2280°F	2.8	4.5	2.3
4	2240°F	2.2	4.0	5.5
8	2240°F	2.2	4.1	5.0
16	2240°F	2.9	4.2	4.3
32	2240°F	2.9	4.3	3.6

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E R R A T A

Page 11 - Paragraph 1 - second line - several months should read:
fifty-five days

Page 12 - Paragraph 11 - fourth line - approximately 3 months should read:
approximately 2 months

Page 14 - Paragraph 4 - third line - eliminate Table #272

Page 14 - Paragraph 4 - third line - Table 273 should read:
Table 274

Page 17 - Contents of 2 should be under 3

Contents of 3 should be under 2